

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re patent application of
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Corres. to PCT/EP2004/012714
For: HIGH-TEMPERATURE SOLDERED EXHAUST HEAT EXCHANGER

TRANSLATOR'S DECLARATION

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Sir:

I, the below-named translator, certify that I am familiar with both the German and the English language, that I have prepared the attached English translation of International Application No. PCT/ EP2004/012714, and that the English translation is a true, faithful and exact translation of the corresponding German language paper.

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Date: May 4, 2006


Name: Neil Thomas SIMPKIN

For and on behalf of RWS Group Ltd

High-temperature-soldered exhaust gas heat exchanger

The present invention relates to an apparatus for exchanging heat. In particular, the present invention 5 relates to an exhaust gas heat exchanger for motor vehicles.

Heat exchanger apparatuses nowadays play an increasingly important role in many fields of 10 engineering, in particular automotive engineering, in power plants and in environmental engineering. The components of heat exchanger apparatuses of this type are usually connected or joined to one another by means of welding or soldering.

15 The joining by means of soldering often takes place using what is known as a nickel solder (Ni solder). A nickel solder of this type is distinguished by a high resistance to oxidation and corrosion, but has the 20 drawbacks compared to other solders, such as for example copper solders (Cu solder) that the soldering gap usually has to be at least narrower than 0.1 mm in order to prevent the formation of precipitation products in the soldered seam, which reduce the 25 strength and/or increase the corrosion, that all Ni solders are relatively expensive and that to avoid oxidation of the solder surface, the soldering process is usually carried out in a vacuum soldering furnace, which means that the mass production of nickel-soldered 30 heat exchangers of this type, on account of the process times required in a vacuum soldering furnace, is relatively complex and therefore also expensive.

35 However, the use of Cu-soldered heat exchanger apparatuses represents a problem in many fields, since Cu solder at times does not have the required resistance to corrosion or oxidation in particular when exposed to the fluids flowing through the heat

exchanger apparatus, and consequently it may be damaged at the joint seams, in particular as a result of corrosion or oxidation.

5 Therefore, it is an object of the present invention to provide an apparatus for exchanging heat and a process for producing an apparatus of this type, which overcomes the drawbacks of the prior art.

10 This object is achieved by the apparatus for exchanging heat as claimed in claim 1 and the process for producing such an apparatus as claimed in claim 18. Further preferred embodiments of the apparatus according to the invention form the subject matter of 15 subclaims 2 to 17. Preferred embodiments of the process according to the invention form the subject matter of subclaims 19 to 21.

Accordingly, the apparatus according to the invention 20 for exchanging heat (heat exchanger) has at least one first flow path for a first fluid, which is at least partially delimited by at least one first delimiting element, and a second flow path for a second fluid, which is at least partially delimited by at least one 25 second delimiting element. Exchange of heat takes place between the first fluid and the second fluid.

Moreover, the heat exchanger according to the invention has a first diffusor space, which is connected upstream 30 of the first flow path and is flow-connected to at least one first connection piece, through which the first fluid flows into the first diffusor space. The first diffusor space is at least partially delimited by at least one third delimiting element. Furthermore, 35 there is a second diffusor space, which is connected downstream of the first flow path and is at least partially delimited by a fourth delimiting element, the second diffusor space being flow-connected to at least

one second connection piece, through which the first fluid flows out of the diffusor space.

5 At least one third and one fourth connection piece, through which the second fluid is fed to and discharged from the second flow path, are flow-connected to the second flow path.

10 The heat exchanger according to the invention also has a separating element on the entry and exit sides of the first flow path, which separating element substantially prevents the first fluid from entering the second flow path and/or the second fluid from entering the first flow path, this separating element being connected in a 15 sealing manner to the first and second delimiting elements. The third delimiting element is connected in a sealing manner to the first or second delimiting element or to the separating element.

20 According to the invention, the sealing connections are cohesive connections, at least those connections in which the material forming the cohesive join is substantially directly exposed to the flow of the first fluid consisting of a first connecting material and 25 connections in which the material which forms the cohesive join is not or not directly exposed to the flow of the first fluid consisting of a second connecting material, the compositions of the first and second connecting materials being different than one 30 another.

A connection in which the material which forms the cohesive join is substantially directly exposed to the flow of the first fluid is to be understood as meaning 35 a connection in which the connecting material is acted on directly by the first fluid, in particular in which the first fluid impinges directly on the connecting material or flows directly past it.

The heat exchanger according to the invention allows the connecting material of the respective cohesive connection to be adapted to the prevailing conditions, 5 and in particular the requirements placed on the respective connection with regard to strength, elasticity, temperature, oxidation and/or corrosion resistance. Those subregions of the heat exchanger in which these demands are not especially high can 10 therefore be joined using connecting materials which are often significantly less expensive, whereas connections in regions of the heat exchanger which are exposed to high demand with regard to corrosion, oxidation, temperature, strength and/or elasticity are 15 produced using connecting materials which satisfy the demands in such respects. An additional advantageous factor may be that the use of Cu solder also encompasses wide soldering gaps between the components to be connected, i.e. the components that are to be 20 joined can be manufactured with larger tolerances.

In a preferred embodiment of the present invention, the fourth delimiting element is connected in a sealing manner to the first and/or second delimiting element or 25 a further separating element; in this case too, it is preferable for the connection to be carried out using the first or second connecting material.

If, for example, the fourth delimiting element is 30 cohesively connected to the first or second delimiting element or a further separating element in such a manner that the material which forms the cohesive join is not or not directly exposed to the flow of the first fluid, for example is only exposed to the flow of the first fluid indirectly through diffusion, swirling flow 35 or the like, according to the invention it is possible for this connection of the fourth delimiting element to the first or second delimiting element or a further

separating element to be produced using the second connecting material, since the connecting material is not in this case subject to particularly high demands.

5 It is particularly preferable for the first and/or second delimiting elements to substantially close off the first or second flow path with respect to the environment and with respect to the respective other flow path, so that a transfer of the first fluid into
10 the second flow path or of the second fluid into the first flow path is prevented even in the region of the delimiting elements, and in particular the first and/or second fluid is prevented from escaping from the heat exchanger.

15 It is in this way also possible for the apparatus according to the invention for exchanging heat to be used in an arrangement in which a pressure which is higher than the surrounding environment is present in
20 the first and/or second flow path.

In a preferred embodiment, the first delimiting element, in its main direction of extent, runs substantially parallel to the main direction of extent
25 of the second delimiting element. In this case, it is particularly preferable for the first delimiting element to be arranged at least partially inside the second delimiting element.

30 In a further embodiment, the first delimiting element is arranged at least partially inside the second delimiting element, with the main direction of extent of the first delimiting element, and in particular the direction of flow of the first fluid, not being
35 parallel to the main direction of extent of the second delimiting element and in particular to the direction of flow of the second fluid.

It is preferable for the direction of flow of the first fluid inside the first delimiting element to run at least partially parallel or parallel but in the opposite direction to the direction of flow of the 5 second fluid inside the second delimiting element.

In a particularly preferred embodiment of the present invention, the first and/or second delimiting element is a tube which particularly preferably at least in 10 part has a substantially rectangular, square, circular or elliptical cross section, the cross section of the second delimiting element being larger, preferably by a multiple, than the cross section of the first delimiting element.

15 It is preferable for the separating element to be a tube plate which is provided with openings into which the first delimiting elements are fitted. It is preferable for the openings in the tube plate to have 20 cross sections which substantially correspond to the cross section of the first delimiting element, so that the separating element surrounds the first delimiting element in a substantially positively locking manner preferably in an end portion.

25 The separating element is preferably surrounded in a substantially positively locking manner by a subregion of the second delimiting element, particularly preferably by an end portion of the second delimiting 30 element. In a further embodiment, the separating element bears at its end against the second delimiting element. In a further embodiment, the separating element surrounds the second delimiting element in a substantially positively locking manner at the end 35 side.

In one embodiment of the present invention, the third and/or fourth delimiting element is/are connected in a

sealing manner, in particular cohesively, to the first or second connection piece, respectively. It is preferable for the material which forms the cohesive join in the case of the cohesive connection of the 5 third or fourth delimiting element to the first or second connection piece also to be the first or second connecting material.

In a particularly preferred embodiment of the present 10 invention, the second delimiting element is connected in a sealing manner to the third or fourth connection piece, in particular by a cohesive connection using the second connecting material. It is assumed that the material which forms the cohesive join of the cohesive 15 connection between the third and fourth connection piece and the second delimiting element is not directly exposed to the second fluid, in which case the second connecting material is selected in such a way that it is able to withstand a possible oxidizing or corrosive 20 effect of the second fluid substantially unaffected.

It is preferable for the first fluid to be at a higher 25 temperature than the second fluid, the first fluid preferably being a gas, in particular an exhaust gas from a combustion process and particularly preferably the exhaust gas from a motor vehicle engine. It is preferable for the temperature of the first fluid when it enters the heat exchanger to be higher than the temperature of the second fluid when it enters the heat 30 exchanger, preferably 100°C to 1000°C higher than the temperature of the second fluid, for preference 300°C to 900°C above the temperature of the second fluid and particularly preferably 500°C to 800°C above the temperature of the second fluid.

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The second fluid is preferably a liquid, preferably a refrigerant, and particularly preferably cooling water,

in particular the cooling water of a motor vehicle cooling circuit.

5 It is particularly preferable for the corrosion resistance, oxidation resistance and/or thermal stability of the first connecting material to be higher than the corrosion resistance, oxidation resistance and/or thermal stability of the second connecting material. In particular, the corrosion resistance of
10 the first connecting material with respect to moisture, sulfur compounds, carbon compounds and in particular acids thereof is higher than that of the second connecting material.

15 The cohesive connections of a heat exchanger apparatus according to the present invention are preferably connections which are produced by soldering, preferably brazing and particularly preferably by high-temperature soldering. In this case, it is preferable for the first
20 connecting material to be selected from the group consisting of nickel solder (Ni solder), gold solder (Au solder), cobalt solder (Co solder) and the like. In particular, the group from which the first connecting material is selected also encompasses further solders
25 which contain alloys of the metals nickel (Ni), silver (Ag), gold (Au) or cobalt (Co), these metals representing a significant constituent of the alloys in question.

30 A particularly preferred nickel solder, in addition to nickel as a significant constituent, also contains, as further constituents, 0-25% by weight chromium, 0-10% by weight silicon, 0-85% by weight boron, 0-11% by weight phosphorus. Moreover, further nickel solders
35 also contain 0-4.5% by weight iron and 0-16% tungsten. Examples of particularly preferred nickel solders include the solders Ni102, Ni105 or Ni107.

A preferred gold solder consists of 100% by weight gold, in particular if the layer of solder has been applied chemically. Further gold solders contain up to 20% by weight nickel.

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The second use material is preferably selected from a group of materials consisting of copper solder (Cu solder), silver solder (Ag solder), brass solder and the like. In particular, the group from which the 10 second connecting material is selected also includes further solders which contain alloys of the metals copper (Cu), zinc (Zn) or silver (Ag), these metals representing a significant constituent of the alloy in question.

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A particularly preferred copper solder consists of 100% by weight copper, with further Cu solders, to which up to 3% by weight nickel has been admixed, preferably also being used. Further copper solders contain up to 20 15% by weight nickel and/or up to 47% by weight zinc and/or up to 17% by weight Sn and/or up to 13% P. Solder of this type are also known as brass solders.

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The process according to the invention for producing an apparatus according to the invention for exchanging heat achieves the object by virtue of the fact that the delimiting elements and the separating elements (components) are cohesively connected to one another in a single joining process.

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Therefore, in this joining process both the cohesive connections which are produced using the first connecting material and the cohesive connections which are produced using the second connecting material are 35 produced in a single joining process, with the parameters of the joining process being selected in such a way as to effect reliable and permanent connection of the components.

According to the invention, the elements, i.e. the separating elements and/or at least one of the delimiting elements, prior to the joining process are 5 provided at least in regions with the first and/or second connecting material; in particular, the connecting materials are applied to the contact regions of the components, i.e. the contact regions between the separating elements and the delimiting elements, and if 10 appropriate the connection pieces.

It is preferable for the connecting materials to be applied by spreading, rolling or spraying on the connecting material, in particular by applying an 15 adhesive followed by a soldering powder, a paste, a foil or a strip or by electrodeposition of the connecting material or a thermal spraying process.

Connecting regions in which in the fully joined heat 20 exchanger the material which forms the cohesive join is directly exposed to the flow of the first fluid are in this case provided with the first connecting material, whereas connecting regions in which the material which forms the cohesive join in the fully joined heat 25 exchanger is not or not directly exposed to the flow of the first fluid are provided with the second connecting material.

Prior to the joining process, the components provided 30 with the connecting material are connected to one another in a positive and/or nonpositive manner, in such a manner that their arrangement with respect to one another substantially corresponds to the arrangement of the components in the fully joined heat 35 exchanger. The components which are positively and/or nonpositively connected to one another are then fed to the joining process.

During the joining process, the components which have been provided with the connecting materials, in particular the separating elements and the delimiting elements, are exposed to a temperature of between 900°C 5 and 1300°C, preferably between 1000°C and 1200°C, and particularly preferably between 1050°C and 1150°C, for a predetermined period of time. As a result, during the joining process, the connecting material which has been applied to the elements of the heat exchanger device 10 changes in such a way that the connecting materials melt and as a result the components are cohesively connected to one another in a sealing manner.

15 In a particularly preferred embodiment of the present invention, the joining process takes place under a shielding gas atmosphere, in which case the shielding gas is selected from a group of gases consisting of hydrogen gas (H₂), nitrogen gas (N₂), argon (Ar), krypton (Kr), xenon (Xe) and the like, as well as any 20 desired combinations thereof.

On account of the shielding gas atmosphere during the joining process, an undesirable change to the surface or the structure of the connecting material and/or of 25 the components, for example through oxidation, can be avoided, and as a result the quality of the connection, in particular the strength and durability of the connection, can be ensured.

30 Within the context of the process for producing the heat exchanger apparatus according to the invention, it is particularly preferable for the joining process to be carried out continuously, i.e. the components which have been positively and/or nonpositively connected to 35 one another are heated for example in a continuous furnace, a walking-beam furnace or the like. It is in this way possible to avoid delays during production of a heat exchanger according to the invention on account

of the in some cases long process times of a high-temperature soldering process in a vacuum furnace. A continuous joining process of this type is positively influenced in particular by the use of a shielding gas 5 during the joining in a continuous furnace.

Further features of the present invention will emerge from the following detailed description of a particularly preferred embodiment in conjunction with 10 the drawing, in which:

Fig. 1 shows an exploded view of a heat exchanger according to the invention;

15 Fig. 2 shows a side view of a further embodiment of a heat exchanger according to the invention;

Fig. 3 shows a sectional view of a heat exchanger as shown in Fig. 2.

20 Figures 1 to 3 show heat exchangers according to the invention in particular for use as exhaust-gas heat exchangers in a motor vehicle.

25 The heat exchangers have first delimiting elements 1, through which a hot exhaust gas flows, and a second delimiting element 2, through which a liquid coolant flows. The delimiting elements 1 run substantially parallel to the main direction of extent of the 30 delimiting element 2 (not illustrated) and are arranged inside the delimiting element 2. At the heat exchangers shown in Figs. 1 and 2, the exhaust gas enters the first delimiting elements 1 from the right and emerges to the left or upward, respectively.

35 The separating element 3 is arranged substantially orthogonally to the main direction of extent of the second delimiting element 2. In a front end region, the

separating element 3 is connected in a sealing manner to the second delimiting element 2, the sealing connection being formed by a cohesive connection 10 using the first or second connecting material.

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The separating element 3 has openings which substantially correspond to the cross sections of the first delimiting elements 1 and into which the first delimiting elements 1 are fitted, so that they are each 10 surrounded, in a substantially positively locking manner, by the separating element 3 in one of their end regions. The first delimiting elements 1 are connected to the separating element 3 in a sealing manner in their end regions, the sealing connection being formed 15 by a cohesive connection 11 using the first connecting material, since the cohesive connection 11 is exposed to the full temperature of the exhaust gas and the corrosive action of the exhaust-gas condensate.

20 In the region of the rear end, at the opposite end from the separating element 3, of the second delimiting element 2, the heat exchanger apparatus shown has a further separating element (not shown), the further separating element preferably being surrounded in a substantially positively locking manner in a similar 25 way to in the front region, by the end region of the second delimiting element 2 and being connected thereto in a sealing manner by a cohesive connection. Similarly to in the front region of the heat exchanger, there is 30 a sealing connection between the first delimiting elements 1 and the further separating element in the rear end region of the first delimiting elements 1, the connection being made to the further separating element (not shown), which surrounds them in a substantially 35 positively locking manner.

In their rear regions, the heat exchangers shown in Figures 1 and 2 have a fourth delimiting element 5.

Between the fourth delimiting element 5 and the second delimiting element 2 there is a sealing connection which is formed in a cohesive connection 12.

5 Depending on the strength of the corrosive and/or oxidizing action of the exhaust gas flowing through the first delimiting elements 1 on the connecting materials of the cohesive connections between the respective separating elements, the delimiting elements and the
10 respective connection pieces, and depending if appropriate on whether and to what extent the connecting materials of the cohesive connections are exposed to the exhaust-gas condensates, these cohesive connections may be produced using the first and/or
15 second connecting material.

In the region of the cohesive connection 12 between the fourth delimiting element 5 and the second delimiting element 2, the connecting material which forms the
20 cohesive join is exposed to exhaust gas which has already cooled down, and consequently this sealing connection can be made using the second connecting material. However, since the corrosive action of the exhaust-gas condensate may still be present, here too
25 it is preferable to use the first connecting material.

Fig. 1 shows the third delimiting element 4 in the form of an illustration which is taken from the second delimiting element 2. The third delimiting element 4
30 touches the end region of the second delimiting element 2 in a substantially positively locking manner; it is cohesively connected in a sealing manner to the second delimiting element 2 by the joining process. Depending on the extent to which the material which forms the
35 cohesive join in the region of the connection between the third delimiting element 4 and the second delimiting element 2 is exposed to the exhaust gas, the cohesive connection 12 between the third delimiting

element 4 and the second delimiting element 2 is produced using the first or second connecting material.

5 The third delimiting device 4 and the fourth delimiting device 5 are connected in a sealing manner to first and second connection flanges 6, 7. The sealing connection between the first and second connection pieces 6, 7 and the third or fourth delimiting element 4, 5 is formed as a cohesive connection 13 or 14, respectively. The 10 cohesive connections 13 and 14 may be welded or soldered; in the latter case, it is preferable to use the second connecting material for cost reasons and because the connections are not directly exposed to the flow of the first fluid.

15

In its rear, lower region and in its front, upper region, the second delimiting element 2 has third and fourth connection pieces 8 and 9, respectively, which are connected in a sealing manner to the second 20 delimiting element 2. The sealing connections between the connection pieces 8, 9 and the second delimiting element 2 are designed as cohesive join 15, 16, the material which forms the cohesive join being the second connecting material, since it is not exposed to the 25 flow of the exhaust gas, and therefore there are no particularly high demands as regards resistance to corrosion and/or oxidation imposed on the connecting material in the region of the connections 15, 16.

30 The exhaust gas which flows through the heat exchanger flows through the connection piece 6, which is connected to the third delimiting element 4, into the first diffusor space, which is formed by the third delimiting element, and then out of this first diffusor 35 space through the first delimiting elements 1, which are designed in the form of rectangular tubes. After the exhaust gas has flowed through the first delimiting elements 1 along first flow paths, in the rear region

of the heat exchanger it passes into the second diffusor chamber, which is delimited by the fourth delimiting element 5, and it then flows out of the second diffusor chamber through the second connection 5 flange 7.

The coolant at least partially flows through the heat exchanger illustrated in a direction of flow which is substantially parallel or parallel but opposite to the 10 direction of flow of the exhaust gas.

In the situation in which the coolant flows parallel to the exhaust gas, the coolant flows through the fourth connection piece 9, which is flow-connected to the 15 second delimiting element 2, into the second flow path, which is delimited by the second delimiting element, and then back out of this second flow path through the third connection piece 8.

20 If the coolant flows parallel but opposite to the exhaust gas, the coolant flows into the second flow path through the third connection piece 8. In the front region of the heat exchanger, the coolant, after it has taken up heat from the exhaust gas as it flows through .
25 the second delimiting element, emerges again from the second flow path through the fourth connection piece 9, which is flow-connected to the second delimiting element 2.